Mrs: Balch —
from H. P. Beck —
March 1842 —

Storms. 7

INTRODUCTION.

"EVERY beginning is difficult;" and to render the following work, which is the beginning of our knowledge on the causes of storms, the more easy to be comprehended, I have thought proper, even at the expense of much repetition, to give in advance a general outline of the whole theory, in one connected chain of cause and effect, following nature in her manner of operating, in producing these meteors.

The paper which was read to the British Association, in September, 1840, contains this outline; and, as the whole work is intended both to develop the cause of storms, and to exhibit the manner in which, according to the strict rules of induction, the development was gradually made, I present that paper here, as an introduction to the whole.

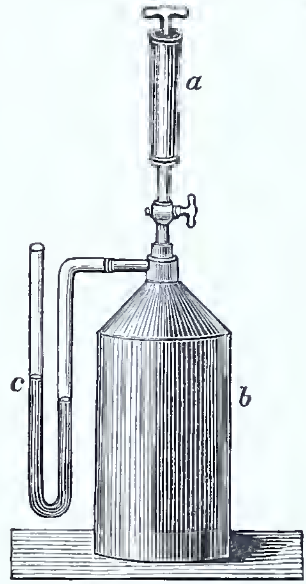
Mr. Espy's paper "On Storms," which excited much attention, was appointed for half past twelve o'clock, and that hour having now arrived, the President, Professor Forbes, called on Mr. Espy, who commenced by stating that he had found by examining simultaneous observations in the middle of storms, and all round their borders, that the wind blows inward on all sides of a storm towards its central parts; towards a point if the storm is round, and towards a line, if the storm is oblong, extending through its longest diameter. Mr. Espy stated that he had been able to investigate

within the last five years seventeen storms, without discovering one exception to the general rule. He could only now give a specimen of the manner in which he had proceeded. He presented a map of Great Britain, on which were drawn arrows representing the course of the wind on the night of the sixth of January, 1839. (See 171.)

From this and from documents which Mr. Espy proceeded to read, it appeared, that during those hours the wind was blowing a violent gale on the north western part of the island from the north west, on the south western parts from the south west, and on the south eastern parts a strong gale from the south east and south south east; and that in the middle parts of the island it changed from south easterly to south westerly about those same hours — the change taking place about two hours sooner on the west side of the island than on the east side in the central parts, but much sooner in the northern parts than in the southern. The barometer also fell sooner in the northern and western parts than in the southern and eastern. From these two circumstances he thinks it highly probable that this storm moved not exactly towards the east, but a little south of east, and if so, it would be similar to some storms which he had examined in the United States. He mentioned one in particular, which occurred on the 26th of January, 1839, whose north north east and south south west diameter reached at least seven hundred miles, while its diameter from west north west to east south east was probably not more than three hundred. (134.) The south border of this storm certainly travelled towards the south of east, and Mr. Espy found that in this storm, as in many others, the barometer fell sooner to the north and west than to the south and east. A much greater difference however depended on the longitude than on the latitude of places. The barometer was at its minimum at Cape Wrath, in the north west corner of Scotland, two hours and a half sooner than at the Calf of Man, five hours sooner than at Edinburgh, and thirteen hours and a half sooner than at Thwaite, in Suffolk. Mr. Espy then stated that he had examined the data furnished by Col. Reid, of several hurricanes in the West Indies, and found conclusive evidence that the wind blew inwards to a central space in all these storms. (Sect. V.) Diagrams of two were exhibited: — one on the 3d of October, 1780, in which Savannah-la-Mar was destroyed. In that storm, at its very height, the wind at Savannah-la-Mar, on the south side of the Island of Jamaica, was south — and nearly opposite to that point, on the north side of the island, the wind was north east, or nearly in an opposite direction, for two hours at the time of the greatest violence of the storm at both places. The other storm was on the 18th of August, 1837, off Charleston, south east. On that day, the ship *Duke of Manchester*

had the centre of the storm pass over her, and, on the same day, the *West Indian* and the *Rawlins*, which were on the south west of the *Duke of Manchester*, had the wind all day from 2, A. M. south west, and at the same time the *Cicero* and the *Yolof*, on the north east of the *Duke of Manchester*, had the wind north east and east north east. The *Yolof* all day, till 8, P. M. Mr. Espy then stated that he had visited the tracks of eighteen tornadoes, and examined several of them with great care, and found that all the phenomena told one tale — the inward motion of the air to the centre of the inverted cone of cloud as it passed along the surface of the earth. (Sect. VII.) From all these facts he demonstrated that there is an inward motion of the air towards the centre of storms from all sides; and he maintained that this is the inference which ought to be drawn from the well known fact that the barometer stands lower in the midst of a storm, than it does all round its borders, (*passim.*) The difficulty is, to account for the continued depression of the barometer, notwithstanding the great rush of air at the surface of the earth towards the place where the barometer stands lowest. So great did this difficulty appear to Sir J. Herschel that he stated to the British Association at Newcastle, that it appeared to him fatal to Mr. Espy's theory. It appeared to Sir John that the only way to account for the fall of the barometer was a centrifugal force in the air, arising from the whirlwind character of storms. Mr. Espy thought it probable that the following statements had never met the eye of Sir John, or he would at least have hesitated before he gave it as his opinion, that the air could not blow in towards a common centre without causing the barometer to rise above the mean. Mr. Forth says, in the second volume of the Philosophical Transactions (Abridged), p. 497, that during a great depression of the barometer on the 8th of January, 1735, he observed that the wind in the northern parts of the island blew from the north east, and on the southern parts of the island from the south west. Mr. Forth modestly adds that he does not understand why the barometer did not rise above the mean by these two concurrent winds. And Mr. Howard says, in a great storm of 1812 the wind on the north of the Humber blew from the east north east, and on the south of the Humber from the south west. Mr. Espy then stated, that he found by calculating according to well known chemical laws, that the caloric of elasticity given out in the air in which a cloud is formed, would expand the air in the cloud about eight thousand cubic feet for every cubic foot of water formed in a cloud by the condensation of the vapor; and he exhibited an instrument, which he calls a Nephelescope, which enabled him to measure, with great accuracy, the expansion due to the evolution of latent caloric, and he found it to agree with the

NEPHELESCOPE.



calculations made on chemical principles. Mr. Espy exhibited the mode of operating with this instrument.

By means of the condensing pump *a*, air may be forced into the glass vessel *b*, and its degree of condensation can be measured by the barometer gage *c*.

After the instrument is charged, the stop-cock is turned, and the pump removed. When the air within acquires the temperature of the air without, a measure is carefully applied to the barometer gage to ascertain how much higher the mercury stands in the outer leg than in the inner; the cock is then turned, and the air permitted to escape, and at the moment of equilibrium, the cock is closed again. Now as the cock is closed at the moment the greatest cold is produced by expansion, the mercury in the outer leg will begin to ascend, and that in the inner leg to descend, because the air within receives heat from without, and the difference of level being measured as before, will indicate the number of degrees cooled by a given expansion.

Mr. Espy shewed that when dry air is used in the experiment, the temperature is reduced about twice as much as when moist air is used, on account of latent caloric evolved in the latter case by the formation of cloud which is plainly visible. (59.) Mr. Espy then proceeded to give the following synopsis of his theory, premising that the numbers he should introduce were not intended to be strictly accurate, and would be subject to many corrections — one in particular, in which no notice had been taken of the specific heat of air under different pressures.

SYNOPSIS.

When the air near the surface of the earth becomes more heated or more highly charged with aqueous vapor, which is only five-eighths of the specific gravity of atmospheric air, its equilibrium is unstable, and up-moving columns or streams will be formed. As these columns rise, their upper parts will come under less pressure, and the air will therefore expand; as it expands, it will grow colder about one degree and a quarter for every hundred yards of its ascent, as is demonstrated by experiments on the nephelescope, (58 to 68.) The ascending columns will carry up with them the aqueous vapor which they contain, and, if they rise high enough,

the cold produced by expansion from diminished pressure will condense some of this vapor into cloud; for it is known that cloud is formed in the receiver of an air pump when the air is suddenly withdrawn. The distance or height to which the air will have to ascend before it will become cold enough to begin to form cloud, is a variable quantity, depending on the number of degrees which the dew point is below the temperature of the air; and this height may be known at any time by observing how many degrees a thin metallic tumbler of water must be cooled down below the temperature of the air before the vapor begins to condense on the outside. The highest temperature at which it will condense, which is variable accordingly as there is more or less vapor in the air, is called the "dew point," and the difference between the dew point and the temperature of the air in degrees, is called the complement of the dew point.[1] (117, 118, 129.)

It is manifest, that if the air at the surface of the earth should at any time be cooled down a little below the dew point, it would form a fog by condensing a small portion of its transparent vapor into little fine particles of water; and if it should be cooled twenty degrees below the dew point, it would condense about one half its vapor into water, and at forty degrees below, it would condense about three fourths of its vapor into water, &c. This, however, will not be exactly the case from the cold produced by expansion in the upmoving columns; for the vapor itself grows thinner, and the dew point falls about one quarter of a degree for every hundred yards of ascent.

It follows, then, as the temperature of the air sinks about one degree and a quarter for every hundred yards of ascent, and the dew point sinks about a quarter of a degree, that as soon as the column rises as many hundred yards as the complement of the dew point contains degrees of Fahrenheit, cloud will begin to form; or, in other words, the bases of all clouds forming by the cold of diminished pressure from upmoving columns of air, will be about as many hundred yards high as the dew point in degrees is below the temperature of the air at the time. (66, 67, 97). If the temperature of the ascending column should be ten degrees above that of the air through which it passes, and should rise to the height of 4,800 feet before it begins to form cloud, the whole column would then be 100 feet of air lighter than surrounding columns; and if the column should be very narrow, its velocity of

[1] The height of the bases of forming cumuli may be ascertained by the following empirical formula: $10300 \left(\frac{t-t'}{t'}\right)$ = height of base in yards; t being the temperature of the air in degrees of Fahrenheit, and t' the temperature of wet bulb swung briskly in the air. (66, 98.)

upward motion would follow the laws of spouting fluids, which would be eight times the square root of 100 feet a second, that is, 80 feet a second, and the barometer in the centre of the column at its base would fall about the ninth of an inch. As soon as cloud begins to form, the caloric of elasticity of the vapor or steam is given out into the air in contact with the little particles of water formed by the condensation of the vapor. This will prevent the air, in its further progress upwards, from cooling so fast as it did up to that point; and, from experiments on the nephelescope, it is found to cool only about one half as much above the base of the cloud as below; that is, about five eighths of a degree for one hundred yards of ascent, when the dew point is about seventy degrees. If the dew point is higher, it cools a little less, and if the dew point is lower, it cools a little more than five eighths of a degree in ascending one hundred yards.

Now, it has been ascertained by aeronauts and travellers on mountains, that the atmosphere itself, free from clouds, is about one degree colder for every hundred yards in height above the surface of the sea; therefore, as the air in the cloud above its base is only five eighths of a degree colder for every hundred yards in height, it follows that when the cloud is of great perpendicular height above its base, its top must be much warmer than the atmosphere at that height, and consequently much lighter. Indeed, the specific gravity of a cloud of any height, compared with that of the surrounding air at the same elevation, may be calculated, when the dew point is given; for its temperature is known by experiments with the nephelescope, and the quantity of vapor condensed by the cold of diminished pressure at every point in its upward motion, and of course the quantity of caloric of elasticity given out by this condensation is known, and also the effect this caloric has in expanding the air receiving it, beyond the volume it would have if no caloric of elasticity was evolved in the condensation of the vapor. (175.) For example, according to the experiments of Professor W. R. Johnson, of Philadelphia, a pound of steam, at the temperature of 212°, contains 1,030° of caloric of elasticity; and as the sum of the latent and sensible caloric of steam is the same at all temperatures, it follows, that a pound of steam being condensed in 1,210 pounds of water at 32°, would heat this water up one degree; and, as the specific caloric of air is only 0.267, if a pound of vapor should be condensed in 1,210 pounds of air, it would heat that air nearly 4°, or, which is the same thing, it would heat 100 pounds of air about 45°. And in all these cases it would expand the air about 8,000 times the bulk of water generated; that is, 8,000 cubic feet for every cubic foot of water formed out of the condensed vapor. And as it requires about 1,300 cubic feet of vapor, at the ordinary temperatures of

the atmosphere, to make one cubic foot of water, if this quantity be subtracted from 8,000, it will leave 6,700 cubic feet of actual expansion of the air in the cloud, for every cubic foot of water generated there by condensed vapor. When hail or snow is formed, the caloric of fluidity given out will produce about an eighth greater expansion. This great expansion of the air in the forming cloud will cause the air to spread outwards in all directions above, causing the barometer to rise on the outside of the cloud, above the mean, and to fall below the mean under the middle of the cloud as much as it is known to do in the midst of great storms. For example, if the dew point should be very high, say 78°, then the quantity of vapor in the air would be about one fiftieth of its whole weight, and if the upmoving column should rise high enough to condense one half its vapor into cloud, it would heat the air containing it 45°, and the air so heated would be $\frac{45}{448}$ larger than it would be if it was at zero, and not so heated. And if we assume a case within the bounds of nature, and suppose the cloud and the column under the cloud to occupy three fourths of the whole weight of the atmosphere, or in other words, if we suppose the top of the cloud to reach a height where the barometer would stand at $7\frac{1}{2}$ inches, and the mean temperature of the whole column 40° warmer than the surrounding air, which we may suppose, for the sake of illustration, to have a mean temperature of zero,) then would the barometer fall under the cloud at the surface of the earth $\frac{40}{488}$ of 22.5 inches, or a little more than an inch and eight tenths.[1]

Though the air will be driven up much higher than the point here assumed, and of course, increase the depression of the barometer, from its specific levity, the cloud will cease to form at greater heights, because the dew point, at these great elevations, falls by a further ascent as rapidly as the temperature; and at greater elevations, it will even fall more rapidly. If, for instance, the air should rise from where the barometer stands at 6 inches, to where it stands at 3 inches, the dew point shall fall about 20°, but the temperature would fall less than 20°, and therefore no vapor would be condensed by such ascent. When a cloud begins to form from an ascending column of air, it will be seen to swell out

[1] *Sittings of the French Academy of Science*, 1839, *page* 715. M. Fournet says, that the parasite clouds which are formed over Mount Pilat do not always redissolve immediately after having been carried beyond the place of their birth, and that the formation of this kind of cloud is accompanied by a very considerable local depression of the barometer. If the formation of a small parasitic cloud produces a considerable depression of the barometer, what ought a great storm cloud to do?

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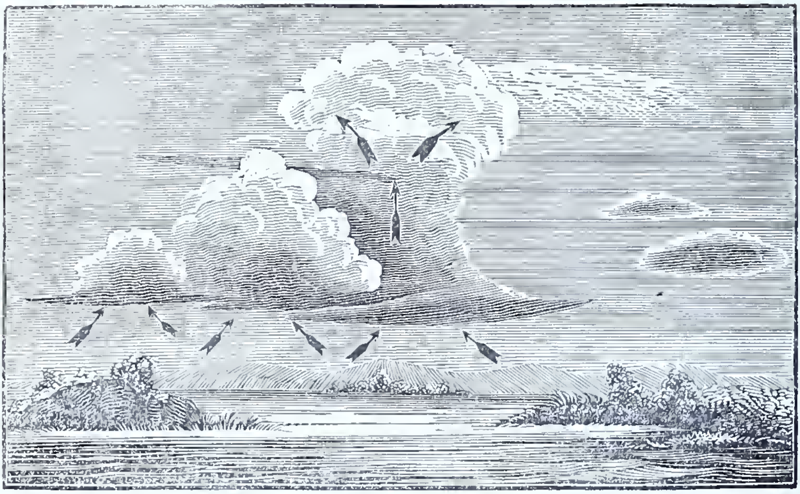

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at the top, assuming, successively, the appearances of 1, 2, 3, generally called cumuli: or, if the upmoving current should be driven out of its perpendicular motion by an upper current of air, the clouds which might then form would be raged and irregular, called broken commuli, as 4. These will always be higher than the base of cumuli, but much lower than cirrus. While the cloud continues to form and swell up above, its base will remain on the same level, for the air below the base has to rise to the same height before it becomes cold enough, by diminished pressure, to begin to condense its vapor into water; this will cause the base to be flat, even after the cloud has acquired great perpendicular height and assumed the form of a sugar loaf. Other clouds, also, for many miles around, formed by other ascending columns, will assume similar appearances, and will moreover have their bases all on the same or nearly the same horizontal level; and the height of these bases from the surface of the earth will be greatest about two o'clock, when the dew point and temperature of the air are the greatest distance apart.[1] The outspreading of the air in the

[1] *On some Meteorological Phenomena observed in the Pyrenees*, by M. Peytier. The geodisic observations, says M. Peytier, that I have made with M. Hossard in the western part of the chain of the Pyrenees, (from the Garronne as far as Saint Jean de Luz,) during the years 1825, '26, and '27, having placed me under the necessity of encamping on the principal mountains of this part of the chain, I have had occasion to make some observations on several meteorological phenomena of some interest, of which I will give an account. 1st. On the clouds. It is extremely rare that there is not any cloud on the chain of the Pyrenees; thus, during the summer of 1826, I saw

upper parts of an ascending column will form an annulus all round the cloud, under which the barometer will stand above the mean; of course the air will sink downwards from its greater weight in the annulus, and increase the velocity of the wind at the surface of the earth, towards the centre of the ascending column, while all round on the outside of the annulus there will be a gentle wind outwards. Any general currents of air, which may exist at the time, will of course modify these motions, from the oblique forces they would occasion. The upmoving current of air

only four days without any clouds: the 12th of May, the 18th of June, the 30th of July, and the 7th of August.

It is in the morning, at the rising of the sun, that the mountains are seen most frequently without clouds, but it is excessively rare that they are not covered before the middle of the day.

When the mountains are seen in the morning, we observe generally at one, two, or three hours, more or less, after the rising of the sun, when the heat begins to be felt, there form in the plains at the foot of the chain, some little clouds, which rise gradually and reach the mountains. If we were placed on a high mountain, we would see these little clouds form and rise sometimes as rapidly as rockets. They group themselves in the mountains, where they frequently form tempests; at other times, they rise slowly, assemble in a mass, on the same level, and form a stratum more or less thick and more or less elevated, that covers the plain and resembles a sea of white vapors.

This stratum, thus formed, rises gradually during the day, (sometimes more than 1000 metres,) and lowers in the evening and in the night. Often, this stratum of clouds rising in the day and lowering at night, remains thus for several days in succession. Very often the clouds dissolve in the night and form again in the day some time after the rising of the sun.

These clouds, when they rise in the mountains, generally follow the direction of the valleys, though the wind has not that direction.

We remarked often in the high valleys some clouds leaning against the two sides of the mountains, whilst the heavens were seen above from the middle of the valley, between the two bands of clouds.

We see again, frequently, a cap of clouds on some elevated peaks, when there are not any on the mass of the chain. Often the clouds cover all one side of the chain, whilst the other side is without any clouds; and we remarked that the side toward France is more often covered than that toward Spain.

These clouds are sometimes seen to ride on the summit of the chain. This happens, when pushed by the wind, the clouds attain the top of the chain, where their weight causes them to fall back to the other side.

We remarked also, sometimes, two strata of clouds moving in different directions. There is then some probability of a change of weather.

When there are two strata of clouds plainly shown, the upper is generally higher than the summit of the chain; it rarely touches the peaks. The difference of the level between the two strata is often very considerable.

These clouds are not level in the rainy weather; they are generally low in time of rain, and much more elevated in storms.

The composition of these clouds does not always appear to be the same; sometimes they are light and transparent, sometimes they are thick and not transparent, and sometimes they are dry, and at other times very humid. I have seen the rain producing the rainbow; this is when a part of the cloud resolves itself into excessively fine rain

The clouds which produce these haloes, appear very elevated, very light, and very transparent.

must of course be entirely supplied by the air within the annulus, and that which descends in the annulus itself. When upmoving currents are formed by superior heat, clouds will more frequently begin to form in the morning, increase in number as the heat increases, and cease altogether in the evening, when the surface of the earth becomes cold by radiation.

The commencement of up-moving columns in the morning, will be attended with an increase of wind, and its force will increase with the increasing columns; both keeping pace with the increasing temperature. This increase of wind is produced partly by the rush of air on all sides at the surface of the earth towards the centre of the ascending columns, producing fitful breezes; and partly by the depression of air all round the ascending columns, bringing down with it the motion which it has above, which is known to be greater than that which the air has in contact with the asperities of the earth's surface.[1] The rapid disturbance of equilibrium, which is produced by *one* ascending column, will tend to form *others* in its neighborhood;[2] for, the air being pressed outwards from the annulus, or at least retarded on the windward side, will form other ascending columns, and these will form other annuli, and so the process will be continued. These ascending columns will have a tendency to approach, and finally unite; for the air between them, as between 2 and 3, (p. xii.) must descend, and in descending, the temperature of the whole column will increase,

[1] On the comparative force of the wind during the twenty-four hours, by Mr. Osler.

Mr. Follett Osler, brought before the British Association, a paper, in which he gave the results of his investigations respecting the direction and force of the wind, deduced from the mean of 26,000 hourly observations, taken by the anemometer, at the Philosophical Institution, at Birmingham, during the years 1837-8, and 1839. We extract one of Mr. Osler's tables.

Table, showing the Relative Force of the Wind for each hour of the day, distinguishing the Seasons; from a mean of the years 1837–8, *and* 1839.

	1 a.m.	2	3	4	5	6	7	8	9	10	11	12	1 p.m.	2	3	4	5	6	7	8	9	10	11	12
Winter.	55	54	49	47	47	48	48	51	50	67	73	82	89	89	85	70	75	65	63	63	63	59	61	57
Spring.	26	28	28	27	29	29	32	41	56	70	80	82	90	89	89	80	81	72	52	45	46	38	33	29
Summer.	19	19	19	19	22	20	18	21	25	40	47	55	58	54	53	44	34	28	27	24	22	19	21	20
Autumn.	19	19	19	19	22	20	18	21	26	40	47	55	58	54	53	44	34	28	27	24	22	20	21	20
Totals,	119	120	115	112	120	117	116	134	157	217	247	274	295	286	280	247	224	193	169	156	153	136	136	126

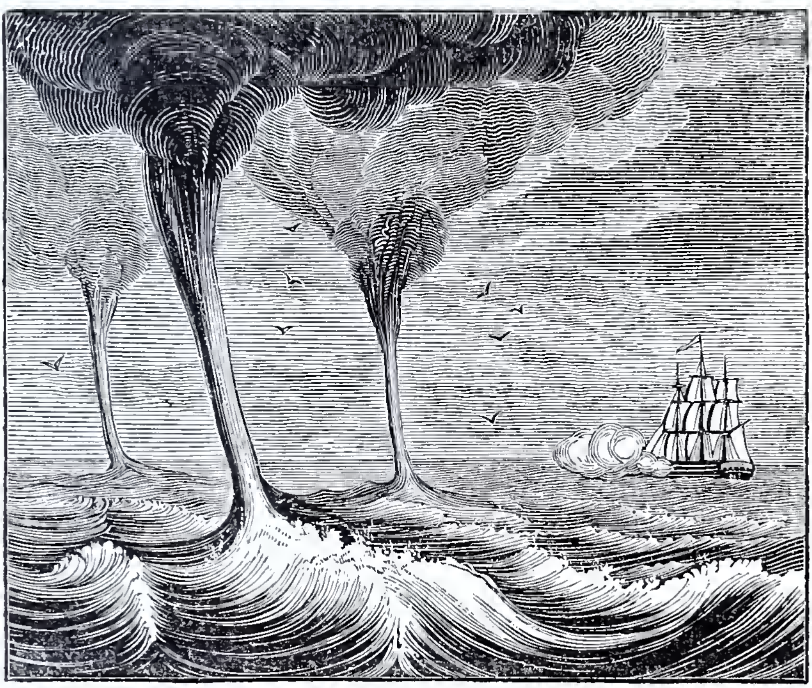
As direction is not regarded in this table, a total of more than one thousand observations is given for each hour of the day. In tabulating these, the curve obtained, is found to be almost identical with that of the thermometer — not only for the whole year, but for each season. The increase in the temperature, however, precedes the rise of the wind by a short interval, until it has attained its maximum force; but as evening approaches, the wind declines more rapidly than the temperature.

[2] The annexed figure, is a copy of three water-spouts, seen by Lieut. Ogden, at one time, on the edge of the Gulf stream, which is described at page

for it is known that the air, at great elevations, contains more caloric to the pound, than the air near the surface of the earth, because it is the upper regions that receive the caloric of elasticity, given out in the condensation of vapor into clouds. Therefore, when the air has descended some time in the middle, between two ascending columns, the barometer will fall a little, or at least not stand so high above the mean as it does on the outside of the two clouds, and so the columns will be pressed towards each other. If one of two neighboring columns should be greatly higher than the other, as 3 and 2, (p. xii.) its annulus may overlap the smaller one, and, of course, the current under the smaller cloud will be inverted, and the cloud which may have been formed over the column thus forced to descend will soon disappear; for as it is forced downwards by the overlapping annulus of the more lofty column, it will come under greater pressure, and its temperature will be thus increased; and it is manifest, that as soon as its top descends as low as its base, it will have entirely disappeared; and, in the mean time, the larger cloud will have greatly increased.

As the air above the cloud formed by an ascending column is

57. For an account of the manner in which one spout, while forming, tends to generate others in its neighborhood, see page 435.



forced upwards, if it contains much aqueous vapor, a thin film of cloud, as over the top of 2, (p. xii.) will be formed in it by the cold of diminished pressure, entirely distinct from the great dense cumulus below; but as the cumulus rises faster than the air above it, (for some of the air will roll off) the thin film and the top of the cumulus will come in contact; and sometimes a second film or cap may be formed in the same way, and perhaps a third and fourth. When these caps form, there will probably be rain, as their formation indicates a high degree of saturation in the upper air. (96.)

When the complement of the dew point is very great, (twenty degrees and more) clouds can scarcely form; for up-moving columns will generally either come to an equilibrium with the surrounding air, or be dispersed before they rise twenty hundred yards, which they must do in this case, before they form clouds. Sometimes, however, masses of air will rise high enough to form clouds; but they are generally detached from any up-moving column underneath, and of course cannot then form cumuli with flat bases; such clouds will be seen to dissolve as soon as they form, and even while forming, they will generally appear ragged, thin, and irregular. Moreover, if the ground should be colder during the day, than the air in contact with it, as it sometimes happens after a very cold spell of weather, then, as the air touching the cold earth will be colder than the stratum above it, ascending columns cannot exist, and of course no cumuli can be formed on that day, even though the air may be saturated with vapor to such a degree as to condense a portion of it on cold bodies at the surface of the earth. Also, if during the whole winter, any part of Siberia, or the northern part of North America, should be so much colder than surrounding regions, that no up-moving columns could be produced, then neither clouds nor snow could be formed.[1] Neither can clouds form of any very great size, when there are cross currents of air sufficiently strong to break in two an ascending current, for the ascensional power of the up-moving current will thus be weakened and destroyed. Immediately after a great rain, too, when the upper air has yet in it a large quantity of caloric, which it received from the condensation of the vapor, the up-moving columns which may then occur, on reaching this upper stratum, will not continue their motion in it far, from the want of buoyancy; therefore, they will not produce rain, nor clouds of any kind, but broken cumuli. Besides, as the air at some distance above the surface of the earth, and below the base of the cloud,

[1] There is a district in Siberia, mentioned by Erman, where, during winter, snow never falls, and clouds are unknown. Report of Committee of Royal Society on Physics and Meteorology, page 45.

is sometimes very dry, and as much of this air goes in below the base of the cloud and up with the ascending column, large portions of the air in the cloud may thus not be saturated with vapor, and, of course, rain in this case will not be produced. Professor Stevelly, of Belfast, told the author, that he knew that clouds are sometimes not saturated. These are some of the means contrived by nature to prevent up-moving columns from increasing until rain would follow. Without some such contrivances, it is probable that every up-moving column which should begin to form cloud when the dew point is favorable, would produce rain, for as soon as cloud forms, the up-moving power is rapidly increased by the evolution of the caloric of elasticity.

On the leeward side of very lofty mountains, there cannot be rain; for as the air on the windward side rises up the sides of the mountain, it will condense all the vapor which can be condensed by the cold of diminished pressure, before it reaches to the top, and even if cloud passes over the top to the other side, it would soon disappear, because in passing down the slope it will come under greater pressure, and thus be dissolved by the heat produced. These are some of the causes which prevent rains at particular times and in particular localities. If, however, the air is very hot below, with a high dew point, and no cross currents of air above to a great height, then, when an upmoving current is once formed, it will go on and increase in violence as it acquires perpendicular elevation, especially after the cloud begins to form. At first the base of the cloud will be flat; but after the cloud becomes of great perpendicular diameter, and the barometer begins to fall considerably, as it will do from the specific levity of the air in the cloud, then the air will not have to rise so far as it did at the moment when the cloud began to form, before it reaches high enough to form cloud from the cold of diminished pressure. The cloud will now be convex below, assuming successively the

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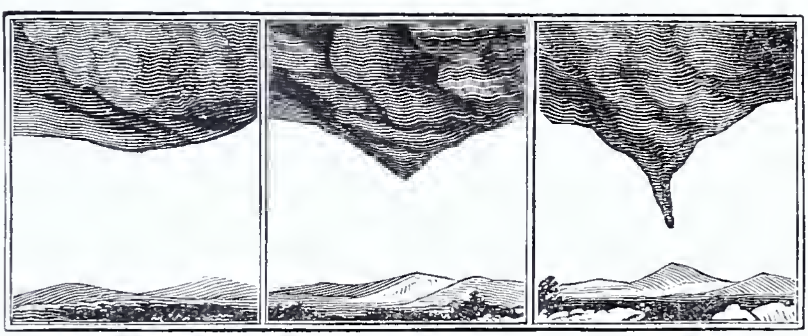


appearances 6 and 7, and its parts will be seen spreading outwards in all directions, especially on that side towards which the upper current is moving, assuming something of the shape of a mushroom. In the mean time, the action of the in-moving current below, and upmoving current in the middle, will become very violent, and if the barometer falls two inches under the centre of the cloud, the air, on coming in under the cloud, will cool by diminished pressure about ten degrees, and the base of the cloud will reach the earth, if the dew point was only eight degrees below the temperature of the air at the time the cloud began to form. The shape of the lower part of the cloud will now be that of an inverted cone with its apex on the ground, as 8, and when a little more prolonged and fully developed, it will be what is called a tornado if it is on land, and a water-spout if at sea.

On visiting the path of a tornado, (see the whole of section VII.) the trees on the extreme borders will all be found prostrated with their tops inwards, either inwards and backwards, or inwards and forwards, or exactly transverse to the path. The trees in the centre of the path will be thrown either backwards or forwards, or parallel to the path; and invariably if one tree lies across another, the one which is thrown backwards is underneath. Those materials on the sides which are moved from their places and rolled along the ground, leaving a trace of their motion, will move in a curve convex behind, those which were on the right hand of the path will make a curve from left hand to right, and those on the left hand of the path will make a curve from right hand to left; and many of these materials will be found on the opposite side of the path from that on which they stood on the approach of the tornado, being carried beyond the centre by their momentum, and moved a little forward by the rear of the tornado. Also those bodies which are carried up will appear to whirl, unless they arise from the very centre; those that are taken up on the right of the centre will whirl in a spiral from left to right, and those on the left of the centre will whirl in a spiral upwards from right to left. On examining the trees which stand near the borders of the path, it will be found that many of the limbs are twisted round the trees, and broken in such a manner as to remain twisted, those on the right side of the path from left to right, and those on the left side of the path from right to left. However, it will be found that only those limbs which grew on the side of the tree most distant from the path of the tornado are broken; for those alone were subject to a transverse strain. The houses which stood near the middle of the path will be very liable to have the roofs blown up, and many of the walls will be prostrated, all outwards, by the explosive influence of the air within, and those houses covered with

zinc or tin, from being air tight, will suffer most.[1] The floors from the cellars will also frequently be thrown up, doors and windows burst outwards, and bureaus and corks of empty bottles exploded. (181.) All round the tornado at a short distance, probably not more than three or four hundred yards, there will be a dead calm, on account of the annulus formed by the rapid efflux of air above, from the centre of the upmoving and expanding column. In this annulus the air will be depressed, because the barometer stands above the mean there, and all round on the outside of it, at the surface of the earth, there will be a gentle wind outwards, and of course all the air which feeds the tornado is supplied from within the annulus. Nor is this difficult to understand, when the depression of the air in the annulus is considered, for any amount may be thus supplied by a great depression. Light bodies, such as shingles, branches of trees, sand, pollen of plants in bloom, grain, fishes,[2] frogs, and tadpoles, (82) and drops of rain or water formed in the cloud, will be carried up to a great height, before they are permitted to fall to the earth, provided there is no whirl to throw them out by a centrifugal force; (32, 33,) for though they may frequently be thrown outwards above, and then descend to a considerable distance at the side, they will meet with an in-blowing current below, which will force them back to the centre of the upmoving current, and so they will be carried aloft again. (32, 82.)

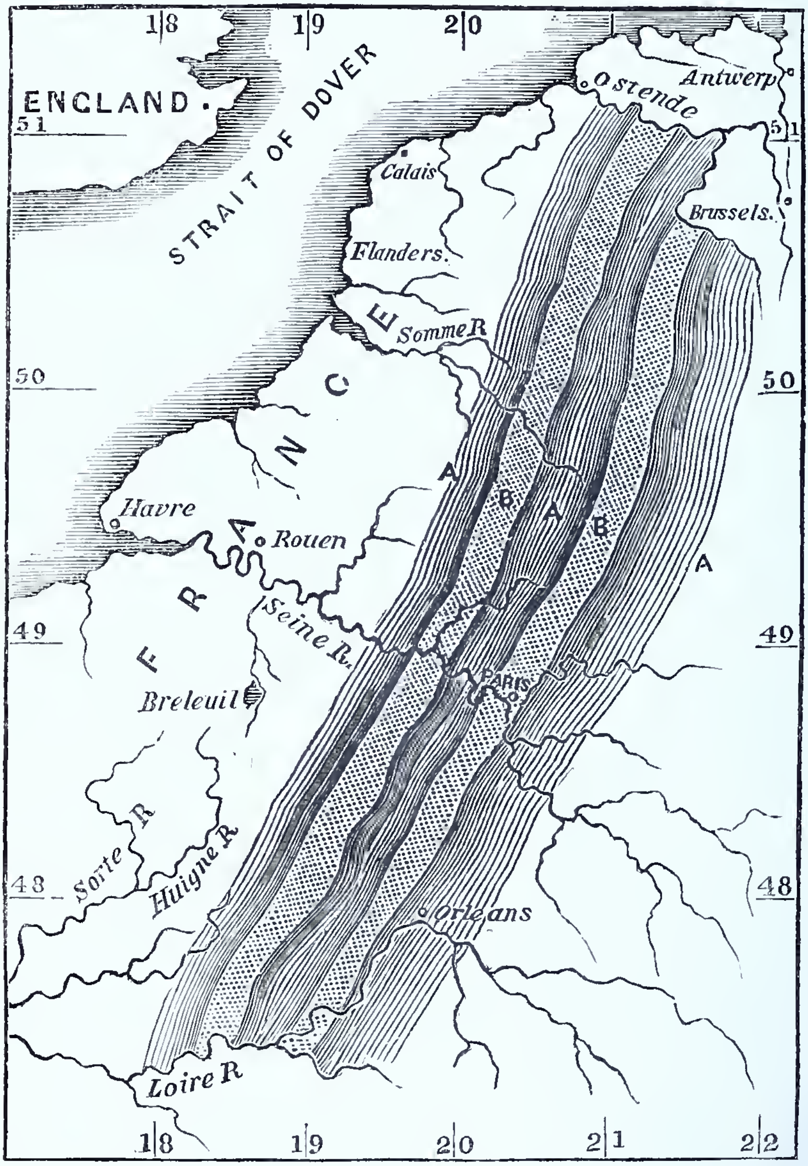
The drops of rain, however, will frequently be carried high enough to freeze them, especially if they are thrown out above so far as to fall into clear air, for this air will in some cases be thirty or forty degrees colder than the air in the cloud. In this case, if the upmoving column is perpendicular, the hail will be thrown out on both sides, sloping inwards as it falls; (183 end) and on examination it will be found that two veins of hail fell simultaneously, at no great distance apart.[3] This hail will frequently be found to

[1] Professor Fisher told me that he knew several instances, in Baltimore, of zinc roofs being carried away, while others, in their neighborhood, not air tight, were undisturbed.

[2] While this article is in the press, June 30, 1841, a shower of fishes (one a squid ten inches long) fell in Boston, and the hail stones which fell at the same place had a saline taste. It was nearly calm at the time, but the wind was very violent in the neighborhood.

[3] The annexed chart is copied from the memoirs of the French Academy, vol. 90. It represents two veins of hail which fell simultaneously not more than eight minutes at any one place, travelling from the Pyrenees to the Baltic with a velocity of about 50 miles an hour. A A A are veins of rain; B B are veins of hail. (69.)

contain many of the materials which were carried up from the surface of the earth; (45) and in cases of violent action, sheets of water will be frozen into cakes of ice, which will break into all sorts of shapes and angles on reaching the surface of the earth.[1]



[1] Mr. Howard says, "On the 21st of June, 1817, the thermometer at Bath in the shade stood at 86°, and on the same day at Lyneham, a water spout inundated a considerable quantity of land and occasioned a rapid rise of the Avon. At

It is indeed probable, (32, 33, 45,) that in all violent thunder storms in which hail falls, the up-moving current is so violent as to carry drops of rain to a great height, when they freeze and become hail. It is difficult, if not impossible, to conceive any other way in which hail can be formed in the summer, or in the torrid zone. (45.) In those countries in which an upper current of air prevails in a particular direction, the tornadoes and water-spouts will generally move in the same direction, because the up-moving column of air in this meteor rises far into this upper current, and of course its upper part will be pressed in this direction, and as the great tornado cloud moves on in the direction of the upper current, the air at the surface of the earth will be pressed up into it by the superior weight of the surrounding air. It is for this reason that the tornado in Pennsylvania generally moves towards the eastward, (*passim.*) The *lower* current does not give direction to the hurricanes of the West Indies, for in the latitude of 15, north,

Salisbury, the storm commenced about 2, P. M., with almost an instantaneous darkness, and a violent rushing of the wind from the N. E. accompanied by sheets of water and large pieces of ice. About 3, the wind ceased from the N. E., and suddenly it commenced blowing from the S W. with such torrents of rain for more than half an hour, that every street was flooded, and the water ran through many of the houses. And at Gloucestershire, on the night of the 15th July, 1808, masses of ice from three to nine inches in circumference did great damage. They appeared like fragments of a vast plate of ice, broken into small masses. The storm rose in the S. W., and died away in the N. E., from which quarter it was opposed by a strong breeze. A similar hail storm, with *rugged pieces of ice*, is mentioned in the 2d vol. page 73; and in page 131, he mentions hail stones five inches long and two inches in diameter, which fell in France in the Upper Morne. And in page 127, he says, pieces of ice of prodigious size fell near Birmingham. In p. 257, the Ohio storm, with stones 13, 14 and 15 inches in circumference, some appeared like snow balls immersed in water and then frozen. Also in page 271, mention is made of hail falling a foot deep, in less than 10 minutes, and becoming a solid mass of ice. Page 319. M. Howard says, the hail stone, which Gilbert mentions as exceeding the strength of eight men to lift it, was doubtless formed of agglutinated hail melting on the surface and freezing within.

In the Orkney spout of the 24th July, 1818, (36,) instead of hail stones of the usual shape "pieces of ice," of almost all forms, were precipitated with the utmost violence. Mr. Caithness attempted to wade out among the hail stones in the direction of the cattle, but the loose ice, he says, slipped below his feet, and sometimes reached his knees. In this way his legs were so much cut by its sharp edges that he was soon obliged to desist.

Many of these stones were not unlike thick, clumsy oyster shells. The whole extent of this hail storm from S. W. to N. E. was little more than 20 miles, and travelled this space at the rate of about a mile in a minute and a half, and lasted, at any one place, not more than eight or nine minutes. The barometer fell from 29.68 to 27.76, on the passage of the spout; or perhaps more, as the minimum may not have been observed, for it did not occur to Mr. Lindsay to note the barometer till the cloud was passing off; sixty geese in one flock were killed, and all the rest so hurt that they soon died; and the milch cows "were struck yeld," or gave no more milk, and indeed would not suffer the people to attempt to milk them any more.

the prevailing direction of the trade winds is north easterly, and there the hurricanes move towards the north west. It is probable, however, they sometimes bend out of their course, to pass over an island, lying near the track, which they would otherwise pursue.

If a tornado should stop in its motion for a few seconds, as it might do, on meeting with a mountain, it would be likely to pour down an immense flood of water or ice, in a very small space, for the drops which would be carried up by the ascending current would soon accumulate to such a degree as to force their way back, and this they could not do without collecting into one united stream of immense length and weight, and of course on reaching the side of the mountain ; this stream, whether it consisted of water or hail, would cut down into the side of the mountain a deep hole, and make a gully all the way to the bottom of the mountain, from the place where it first struck. (192 to 200.)

As the air spreads out more rapidly above than it runs in below, there will be a tendency in storms to increase in diameter, and this tendency will be greater on the north side than on any other, for the efflux above finds less resistance on that side, for a reason assigned in the next paragraph ; therefore it is probable that storms become elongated north and south, and then, if they move towards the east, they must travel side foremost.

At the equator, or at least those parts of it where the trade winds are constant from east to west, it is probable tornadoes travel from east to west. (147.) For as the air in the torrid zone is about 80° in temperature at a mean, and the air in the frigid zone is about zero, the air in the torrid zone is constantly expanded by heat about $\frac{80}{448}$ of its whole bulk in the frigid zone. This will cause the air at the equator to stand more than seven miles higher from the surface of the earth to the top of the atmosphere than at the north pole. The air, therefore, will roll off from the torrid zone both ways towards the poles, causing the barometer to fall in low latitudes, and rise above the mean in high latitudes. This will cause the air to run in below towards the equator, and of course rise there. Now from the principle of the conservation of areas, it will recede more and more to the west as it rises, and of course the upper current of the air, at the equator, probably moves towards the west. However, as the air rolls off above, towards the north, it will be constantly passing over portions of the earth's surface, which have a less diurnal velocity than the part from which it set out, and as from the nature of inertia it still inclines to retain the diurnal velocity towards the east, which it originally possessed, when it reaches the latitude of about 20 or 25 degrees, it will then probably be moving nearly towards the north, and beyond that latitude its motion will be north easterly. The effect of the air rolling off above from the equator towards the poles, when

considered alone, would cause the barometer at the very poles to stand above the mean; but the centrifugal force of the air in the frigid zone, arising from the diurnal revolution of the earth on her axis, produces a countervailing force of considerable power, and flattens the atmosphere at the poles more than the earth is flattened, because it is of greater diameter, and perhaps this may cause the barometer to stand below the mean very near the poles. Let this matter be further examined. As the air in the torrid zone certainly does rise and run out towards the poles above, it *must rise* there in columns and not all over the zone at once, otherwise this whole zone would be covered with eternal cloud, formed by the condensation of the vapor from the cold of diminished pressure as the air ascended.

If violent storm clouds, which necessarily rise to a great height in the upper current, are driven forward in the direction of the upper current, it is probable that the barometer will rise higher in that part of the annulus which is in front of the storm, than in the rear, and if so, a sudden rise of the barometer, in particular localities, may become, when properly understood, one of the first symptoms of an approaching storm. (116 Rationale, 170.) In consequence of the high barometer in front of the storm in a semi-annulus, the air will be forced downwards there, and cause, in some cases a more violent action of the air or wind backwards, meeting the approaching storm, than will be experienced in the rear of the storm. As the barometer will probably be highest in the centre of the semi-annulus, north east of the storm, in middle latitudes, the tendency of the wind to blow outwards on all sides from the region where the barometer stands highest, may cause the wind in the beginning of the storm to blow so as to appear to whirl from left to right, on the east side of the storm, and from right to left on the west side. (p. 240.)

As the air comes downwards in the semi-annulus in front of the storm, it will come under greater pressure, and therefore any clouds which it may contain will probably be dissolved by the heat of greater pressure;[1] consequently, on the passage of the annulus it will probably be fair weather. (p. 241.) Also, as the air above always contains more caloric to the pound than the air below, more especially that which has just spread out above from a storm cloud, containing the caloric recently evolved from the condensing vapor, there will be an increase of temperature on the passage of the annulus, partly from the increased pressure, partly from the increased radiation of the hotter air above, (p. 288) but chiefly by the descent of the air itself. In very hot climates, this

[1] An air tight piston, moved in a glass cylinder, will cause a cloud to appear, by rarefying the air; and to disappear, by condensing it.

increase of temperature in front of the storm will be very sensibly felt. (page 241.) The increased pressure in the annulus round a volcano, when it suddenly bursts out, will sometimes, under favorable circumstances, be very great, and of course the air will be depressed from a great height; so that some portion of the very air which has gone up in the central parts of the ascending column, and formed cloud by the cold of diminished pressure, may be forced down to the surface of the earth, bringing with it the caloric of elasticity which it received from the condensing vapor; if so, the heat experienced at the time of this descent will be very great.

These hot blasts of air will alternate with cold blasts; for the air which is forced down from great heights in the annulus will not only be very hot, but very dry, having condensed its vapor in its previous ascent. Now, when this hot dry air flows inwards again towards the volcano, and ascends, it will not form cloud, because of its want of vapor, and therefore the process of cloud-forming will cease, and consequently hail and rain will cease too, until more air, from a greater distance, that has not been deprived of its vapor, flows in and ascends. Then cloud will again begin to form, and the violence and rapidity of the outflowing of the air above will be increased by the evolution of the caloric of elasticity — the barometer will rise rapidly in the annulus, and fall in the central part of the ascending column; and these alternations may continue while the volcano is in activity, more particularly if the violence of the volcano itself should be increased periodically.

As air cannot move upwards without coming under diminished pressure, and as it must thus expand and grow cooler, and consequently form cloud, any cause which produces an up-moving column of air, whether that cause be natural or artificial, will produce rain, when the complement of the dew point is small, the air calm below and above, and the upper part of the atmosphere of its ordinary temperature.[1]

Volcanoes, therefore, under favorable circumstances, will produce rain; sea breezes, which blow inwards every day towards the centre of islands, especially if these islands have in them high mountains,[2] which will prevent anyupper current of air from

[1] The relative temperature of the upper air may be known by a series of observations with Pouillet's actinometer. (See art. 170.)

[2] CLINTON HOTEL, NEW YORK, Dec. 20, 1839.

TO PROFESSOR ESPY:

DEAR SIR,—Understanding you are desirous of collecting curious meteorological facts, I take the liberty of communicating to you what I saw in the month of December, 1815, at the island of Owyhee. I lay at that island in the Cavrico bay, in which Capt. Cook was killed, three weeks, and every day during that time, very soon after the sea breeze set in, say about 9 o'clock, a

bending the upmoving current of air out of the perpendicular, before it rises high enough to form cloud, such as Jamaica, will produce rain every day; great cities where very much fuel is burnt, in countries where the complement of the dew point is small, such as Manchester and Liverpool, will frequently produce rain; even battles, and accidental fires, if they occur under favorable circumstances, may sometimes be followed by rain. (Sect. X., *passim.*) Let all these favorable circumstances be watched for in time of drought (and they can only occur then), and let the experiment be tried; if it should be successful, the result would be highly beneficial to mankind. It might probably prevent the occurrence of those destructive tornadoes which produce such devastation in the United States; for if rains should be produced at regular intervals, of no great duration, the steam power in the air might thus be prevented from rising high enough to produce any storm of destructive character. Besides its utility to the farmer, it would be highly useful to the mariner in the following way: As the very time and place of the commencement of the rain would be known, it would be easy to find out in what direction, from the place of beginning, it moved along the surface of the earth, and also its velocity of motion, and the shape that it assumed from time to time in its progress; and this knowledge being extended to the motion of storms on the ocean, will enable the mariner, who has the power of locomotion, to direct his vessel so, when

cloud began to form round the lofty conical mountain in that island, in the form of a ring, as the wooden horizon surrounds the terrestrial artificial globe, and it soon began to rain in torrents, and continued through the day. In the evening the sea breeze died away and the rain ceased, and the cloud soon disappeared, and it remained entirely clear till after the sea breeze set in next morning. The land breeze prevailed during the night, and was so cool as to render fires pleasant to the natives, which I observed they constantly kindled in the evening. I was particularly struck with the phenomena of the cloud surrounding the mountain, when none was ever seen in any other part of the sky, and none there till after the sea breeze set in, in the morning, which it did with wonderful regularity. The mountain stood in bold relief, and its top could always be seen from where the ship lay, above the cloud, even when it was the densest and blackest, with the lightning flashing and the thunder rolling, as it did every day. I passed up through the cloud once, and I know, therefore, how violently it rains, especially at the lower side of the cloud. This rain never extends beyond the base of the mountain; and all round the horizon there is eternally a cloudless sky. The dews, however, are very heavy, and there seems to be no suffering for want of rain. That this state of things continues all the year, I have no doubt, from what an American, by name Sears, who had spent four years there, told me; he said he had seen no change in regard to the rain. CALEB WILLIAMS,

Of Providence, Rhode Island.

JANUARY 2d, 1840. Having read the above, I can safely attest to the truth of what Mr. Caleb Williams writes; but, furthermore, can say it is the same on all the mountains on the different islands of the group.

JOSEPH STEELE, *of Boston.*

one of these great storms comes near him, that he can use as much wind in the borders of the storm as will suit the purposes of navigation — for heaven undoubtedly makes the wind blow for his use, and not for his destruction, provided he becomes acquainted with the laws which govern its motions. From the preceding principles, he will be able to know in what direction a great storm is raging, when it is yet several hundred miles from him, for the direction of the wind alone points it out. If, however, the storm should be of such great length, moving side foremost, that it will preclude the possibility of avoiding it, he will at least be enabled to know in what direction to steer his ship, to get out of the storm as soon as possible. For example, if it shall be found that storms between the United States and Europe always move towards the east, then it will manifestly be improper to scud with the wind in the latter part of the gale, when the wind is blowing from the westward, because this would be to keep in the storm as long as possible. (134, 170.) The sailor also will be able to know when he is out of danger; for when a great storm has passed off to the east in middle and high latitudes, and to the north in low latitudes, on the north of the equator, he will know that it never returns; and therefore he will not be afraid to spread his sails to the wind, before the calm of the annulus comes upon him. The mariner will finally be able, by observing storm clouds on their approach, to ascertain the direction in which storms move, for these storm clouds frequently exhibit their front edge above the horizon in the form of an arch; and if the highest part of the arch approaches towards the zenith, then is the storm coming from the point where the arch first appeared.

When a storm has a much greater diameter from north to south than from east to west, the wind will not blow towards a central point, but towards a central line, which may be called the transverse diameter of the storm.

On the northern end of the storm, if it moves towards the east, the wind will change round without a lull, by north towards the west; and on the southern end of the storm the wind will change round without a lull, by south towards the west; but in the middle of the storm the wind will change with a lull from easterly to westerly. (136, 171, *et passim.*)

When the storm is of great length, north and south, the lull in the central parts may be experienced simultaneously, at considerable distances apart, north and south, which could not be the case if the storm was round; and as this occurs frequently on the coast of the United States, it is certain, from that circumstance alone, that the centre of storms is frequently a line of great length; and moreover, as the wind in the first part of the storm is frequently south east, and in the last part of the storm north west; and as

the barometer falls successively from north of west to south of east,[1] it seems highly probably that these storms of oblong form move towards the south of east *(passim.*[2]*)*

In the West Indies, from Barbadoes to Jamaica, it is known, by the invaluable labors of Redfield and Reid, that the hurricanes

[1] See diagram at the end of Appendix, pp. 550 and 551.

[2] It seems probable, from the following facts, extracted from Orlando Whistlecraft's Climate of England, that thunder storms in England also travel from north of west to south of east.

Page 2. In summer, too, a south east wind always prevails in the eastern countries before the great thunder storms, which by night spread themselves over the greatest part of England. These storms are evidently aided in their rise and progress, or passage to the eastward, by a south west or west wind behind them, which combats against the sea breezes so usual in Kent, Essex, Suffolk, &c., from south east or east during hot days.

Page 7. The south east wind blows in July with the hottest and clearest days for nearly a week in the eastern counties, until vapors arise with a south west current and form distant ranges of rocky clouds in the south west horizon. These and the white and round detachments of cirrocumulus in trains across the zenith, are the first clouds after clear and hot days indicating a change, which takes place by the south western clouds coming on with a severe thunder storm by night for many hours, while the wind continues east or south east, until it passes, when it veers to the south west, whence the storm arose.

Page 10. On the night of the 9th August, 1787, a dreadful thunder storm came on. This was introduced by a fine and hot week, with easterly wind, and the storm came on as usual from south west, whither the wind afterwards veered.

Page 22. In a hot and clear sunshine, so much moisture is drawn up by evaporation, that many distinct cumuli are formed by 10, A. M. in the otherwise clear sky. These increase in size till about 2, P. M., after which they decrease, and at sunset we have none again in view.

Page 27. The cumulus is truly the day-cloud, beginning to form itself in a previously clear morning, increasing till 2, P. M., and then decreasing, until at sunset no cloud again appears. In this case we see a mere speck of vapor, at about 10, A. M. in a summer's day, accumulating till a semicircular body is formed, having a flat base, while the upper part is somewhat rocky in appearance.

Page 28. As the cumulus is about to pass into the nimbus, the middle of the cloud will represent the neck of a mushroom, and the summit spreads and overhangs the base in a most striking manner, and the tops of these clouds may be compared to the ebullition or at least to the effervescing of some fluid.

Page 30. It has been long observed by meteorologists, that a south east wind (in the eastern counties at least,) precedes the most violent thunder storms, and that the storm itself works its way in a higher current from the westward.

Page 67. On the 23d May, 1830, an extraordinary cloud began to rise at 6, P. M., and veiled the south west in blackest hue for two hours. It made its way against the opposing current below with a continued blaze of blue lightning, and continued over us about an hour.

And on the 3d of June, at 4, P. M., a violent storm came up against the lower current, which was east north east.

On 26th June, 1833, a thunder storm came from south west, wind north east. The same phenomenon occurred on the 24th August, 1834, and also on the 13th October, 1836, and 29th June, 1838.

there move from the south east to north west; therefore if the wind springs up violent from north west in those parts, the mariner may be sure that a hurricane is coming upon him if he remains stationary; and if it springs up in any other direction, he will know in what direction to sail to avoid its violence.

This paper gave rise to a very interesting conversation, but from the great length of the paper itself, we can only direct attention to the leading points of the discussion. Professor Stevelly called the attention of the Section to the fact that he had, at the Edinburgh meeting in 1834, used the principle of cold, produced by rarefaction, to explain what he called the secondary formation of clouds, and thus the propagation of storms; and even assigned this rarefaction as the cause of summer hail, (see *Athen.* No. 361, 1834).

He objected to the main position, however, in Mr. Espy's theory, that *the fall of temperature* caused by the expansion of any body of air rendered light, by being loaded with moisture as it rose in the atmosphere, was the same as the *constituent temperature of the strata of air* into which it rose, that is, of equal tension. He deduced from the numbers given by Poisson, that it was much greater; that a cloud would be colder and not hotter than the surrounding air, and therefore the violent ascending vortex calculated upon by Mr. Espy, would not exist.

Professor Forbes had three objections to Mr. Espy's theory, 1st, the small funnel at the centre of a tornado, through which Mr. Espy supposed the air to rise, would be insufficient to vent all the air which would rush, during a tornado, with the frightful velocity we know it to attain, through the constantly enlarging rings surrounding that central funnel, to an extent of many hundred miles: 2d, as the tornado had a progressive motion, as Mr. Espy admitted, it would be more difficult than Mr. Espy supposed to deduce from the way in which the trees in its path were thrown, the actual course of the atmospheric particles at any instant, as each would move with a motion compounded of two motions, both varying in relative direction and magnitude: 3d, he thought that all the vapor in the air would be condensed into cloud much sooner than Mr. Espy supposed, and he thought it certain that the small amount of heat given out by the vapor would not suffice to expand the air in the funnel to the extent required, if Mr. Espy's views were correct.

To the first objection Mr. Espy replied, that the objection was answered in the paper itself; in which it was shown that the air was calm all round the tornado, within a few hundred yards, and that it ought to be so on his principles.

To the second he answered, that Mr. Redfield had laid down a test, by which it could be ascertained with absolute certainty

whether or not the air blew in towards the centre, and that was, that the trees, in the central line of the path, should be found lying parallel with the path; and he stated that this had been found to be the case in all the tornadoes which had been examined.

To the third he answered, that if all the vapor should be condensed as Professor Forbes thinks, then the effects produced would be much more violent. Professor Forbes would find, that if *all* the vapor which is in a mass of air when the dew point is 73°, (and it is sometimes higher than that when tornadoes occur,) should be condensed, the latent caloric given out would heat the air more than 70°; and in case of hail, nearly 80°, by the addition of the caloric of fluidity. Professor Forbes would find, by a rigid examination of the subject, that all the vapor is never condensed, because the dew point, at great heights, falls by expansion faster than the temperature.

As to the question whether Mr. Redfield and Colonel Reid's theory of a whirl, or Mr. Espy's radial theory, was most accordant with fact, Mr. Osler said, that from the investigation he had given this subject, he was convinced that the centripetal action described by Mr. Espy took place in most hurricanes. The particulars, he, Mr. Osler, had collected, together with the indications obtained from the anemometers at Birmingham and Plymouth, satisfied him that the action of the great storm of the 6th and 7th of January, 1839, was not rotatory at the surface of the earth when it passed across England. He differed, however, both from Mr. Espy and Mr. Redfield in one essential point, for he believed it would be almost impossible to have a violent hurricane, without, at the same time, having both rotatory and centripetal action. A storm might very probably be generated in the first instance, in the manner accounted for by Mr. Espy, or by the action of contrary currents; in the first case, the rush of air towards a spot of greater or less diameter, would not be perfectly uniform, owing to the varying state of the surrounding atmosphere; this, together with the upward tendency of the current, would, in some cases, produce a violent eddy or rotatory motion, and a whirlwind of a diameter varying with the cause would ensue; the centripetal action would thus be immensely increased, the *whirlwind itself* demanding a vast supply of air, which would be constantly thrown off spirally upwards, and diffused over the upper atmosphere, thus causing the high state of the barometer which surrounds a storm. He further stated, that he had brought his theory of the combined action of centripetal and rotatory motion before the meeting of this Association at Birmingham, and a short notice of it would be found in the reports of the Sections. If no rotatory action takes place, he believed that we merely experienced the rush of air which necessarily precedes a heavy fall of rain or thunder

storm, but he believed that nothing violent enough to be called a hurricane could take place, unless a violent rotatory or whirling action be first produced, and that in many, and perhaps most cases, the rotatory portion is not in contact with the earth.

Mr. Arch Smith said, there was one point which must not be overlooked in any correct comparison of the rival theories. From the principle of the conservation of areas it was perfectly certain, that if a storm was caused in the manner supposed by Mr. Espy, there must be a rotation, greater or less, in the centre. Because, unless the motion of all the currents was accurately directed to one point, or at least their *moments* in a horizontal plane were equal to zero, which was infinitely improbable, a motion of rotation must be the result, as in the instance of the motion of water in a funnel, cited by Mr. Espy.[1] If the central space of comparative rest were large, the whirl might be imperceptible; but if small, as in the case of a water-spout, it must be considerable. Without embracing either theory, he thought it difficult to conceive, as he understood Mr. Osler to do, the motion of rotation to be the primary, and the centripetal (which indeed would be centrifugal) force to be the secondary phenomenon. But it was comparatively easy to suppose the centripetal motion to be the primary phenomenon, and quite certain that if so, there must result a secondary phenomenon of rotation, of which indeed some indications appeared in Mr. Espy's maps.

In making some remarks on the preceding paper, Sir David Brewster observed, that it was impossible to form any decided opinion on the subject, from the great want of well ascertained facts; and as Mr. Espy had founded his theory expressly on observations, often made by himself, it was impossible to do justice to his ingenious views until a greater number of facts had been collected. The facts, too, stated by Mr. Espy, were opposed to those observed by others. In the case of hurricanes or tornadoes, the convergency of the aerial currents in the one theory, and their rotatory motion in the other, were not *observed*, but *inferred* from a number of facts; but as Mr. Espy regarded water-spouts as formed in the same manner as tornadoes,

[1] Mr. Espy's experiments with a funnel, are in opposition to the statement made here. He has performed many, and in all instances where care was taken to have the water still, before removing the finger from the lower end, and letting the water run out, it discharged the whole contents without any whirling motion. The same occurred, whether a funnel was used, or a tub with a hole in the bottom. Mr. Espy acknowledges, however, Mr. Smith's doctrine of the conservation of areas to be correct, and he admits it as highly probable, that spouts sometimes whirl one way, and sometimes another; but generally neither way; and in all cases, the whirl, if any, would only be perceptible very near the centre. He first supposed that all spouts whirled, and was only compelled to abandon this notion by the facts themselves.

and as Col. Reid had distinctly stated in his letter to Sir David, already referred to, that he had *actually seen*, from the government house at Bermuda, by means of a telescope, the *water-spout revolving like the hands on the dial plate of a watch*, there could be no doubt that we were at variance about facts. This explicit and distinct *observation* of a rotatory motion by so able and accurate an observer as Col. Reid, was worth a thousand inferences. As to Sir David Brewster's objection, Mr. Espy thought his paper itself contained an answer to it, where he showed that bodies taken up on one side of the tornado, would whirl one way, and bodies taken up on the other side, would whirl the other. And it was worthy of notice, that all Col. Reid's spouts whirl from left to right, and all Mr. Redfield's from right to left, on this side of the equator. Mr. Espy had examined a great many witnesses of the Brunswick tornado, and some saw the materials which went up, whirl one way, and some another, though they were standing together; and Professor Strong and Professor Beck of New Brunswick, saw the materials whirl as the hands of a watch, contrary to the manner Mr. Redfield says this and all other spouts in this latitude, whirl. Professor Phillips must say that he thought the statements of fact connected with tornadoes, as stated in the American journals, were more consistent with Mr. Espy's than with Mr. Redfield's theory; and Col. Reid thinking he saw rotation in a water-spout could not invalidate the abiding evidence from uprooted forests.

Report of the Academy of Sciences, (Paris), on the labors of J. P. Espy, *concerning Tornadoes, &c.*

Committee, Messrs. Arago, Pouillet, Babinet reporter.

Messrs. Arago, Pouillet, and myself, have been appointed by the Academy to make a report to it upon the observations and theory of Mr. Espy, which have for their object the aerial meteors known by the names of storms, water-spouts and tornadoes, which cause so much destruction on land and sea in the vicinity of the Gulf of Mexico. These storms are produced in the same manner in every part of the globe, when a few given circumstances concur in one place.

The labors of Mr. Espy have already considerably occupied the attention of the learned world, and may be considered under three different points of view. First, the facts which he has recognised and substantiated, and the proofs which support them; second, the physical theory, by which he explains them and the conclusions which he deduces from that theory; third, the observations which are yet to be made according to this theory, based upon facts, and the practical rules which the mariner, the farmer, and

the meteorologist will obtain from it ; the two former for their own benefit, the latter for science, which is useful to all.

The facts which result from the numerous documents which Mr. Espy has placed in the hands of the committee, are the following : the motion of the air in the meteor under consideration, called tornado or water-spout, if it is violent, and of small extent; a storm, if it covers many degrees of the earth's surface ; the motion of the air, we say, is always convergent, either towards a single centre, when the tornado has a circular form, and limited extent, or towards a diametrical line, when the tornado or storm is of a lengthened form and extends over many hundred leagues.

If the tornado is very small, in which case the violence of the motion of the air is greater, a cloud is frequently seen in the centre, whose point descends more and more until it touches the earth or sea. Water-spouts are small tornadoes, and the force of these meteors in the south and east of the United States is such, that trees are carried up in the air, and the heaviest objects are overturned, displaced, and transported. Finally, we have only to call to mind the well known storms of the Antilles, which change even the form of the ground over which they pass. We will adopt the technical word tornado to designate the meteor in question, whatever may be its extent or violence. China and the neighboring seas, Central Africa and the south west part of the Indian Ocean, are, like the West Indies, the theatre of meteors of the same nature, and not less disastrous.

In observing at the same moment the force and direction of the wind, which is shown by the overturned trees, the displaced movable objects, in a word, by the traces impressed upon the soil, Mr. Espy proves that in the same instant the motion of all parts of the air which is reached by the tornado is tending towards a central space, point or line, so that if the wind on one side of the meteor blows towards the east, it blows with the same violence towards the west on the other side of the tornado, and frequently at a very short distance from the first place, whilst in the centre, an ascending current is formed of astonishing rapidity, which, after having risen to a prodigious height, spreads out on every side to a certain limit, which we shall soon determine by the observations of the barometer. This ascending current loses its transparency at a certain height, and becomes a true cloud of the kind called cumulus, the base of which is horizontal, and whose height is determined by the temperature and humidity of the atmosphere. The central cloud of the tornado is constantly reproduced, in proportion as it is carried off by the rapid current of the centre ; and, according to Mr. Espy, when rain or hail proceeds from this meteor, which is generally the case, it is the cold, caused by the expansion of the air carried into the higher regions of

the atmosphere, which condenses the water. Electricity, when it appears in the tornado, is not, according to Mr. Espy, essential to the phenomenon.

The existence of an ascending current of extreme violence once placed beyond doubt by the phenomena of the rising of the air, and its motion towards a centre or towards the great diameter of the oblong space occupied by the tornado, being well established by facts, Mr. Espy examines the progressive movement of the whole meteor, which is very slow, compared with the velocity of the wind in the mass of air which becomes at each instant a part of the tornado. Mr. Espy shows that near the latitude of Philadelphia, where cirrus clouds, very elevated as is known, move towards the east, the centre of the tornado moves almost always towards the east, as well as in Europe, where the west wind is predominant; whilst, in the inter-tropical regions, (Barbadoes, Jamaica, the north of the Indian Ocean,) the meteor moves towards the west or north west, following the course of the trade winds. These assertions are also verified with regard to China and the Indian Ocean, according to the maps of Berghous. The barometer, in the centre of the meteor, is sometimes nearly 2.25 of an inch (sixty millimetres,) lower than towards its border, and its limit is marked on all its outline by a closed curve, along which the barometer is found to be at its "normale" height, whilst, on the other side of this line, further from the centre, the barometer is observed to rise, which rise in small tornadoes is .08 of an inch, (two millimetres,) but which may be forty or forty-eight hundredths of an inch, (ten or twelve millimetres) in very extended storms. If the centre of the tornado moves, (which may take place in any direction, when compared with the diametrical line,) and the effects produced by the motion are examined, it is always found that if the meteor has followed in its motion the line of its greatest diameter, the tree which fell the first, indicates a point anterior in the path of the meteor, and the tree which fell last, a posterior point. Thus it is constantly found that the trees which were overthrown with their tops turned towards positions anterior to the centre of the tornado, are covered by trees falling in the direction of the centre at a posterior period. In short, in this same case, the branches of the trees not overthrown, growing on the side farthest from the opposite side of the line which the centre of the meteor takes, have followed the wind and are twisted around the trunk of the trees.

The circumstances favorable to the sudden production of a tornado, large or small, are, according to Mr. Espy, a warm and humid atmosphere, covering a country sufficiently level and extended, still enough to allow that part of the air which is accidentally the least dense, to rise to a great perpendicular height above the middle of the heated space which is charged with trans-

parent vapor; moreover, in the higher regions, a cold and dry air, whose situation and especially whose density contrasts with that of the ascending current which dilates, cools, loses its transparency by the precipitation of its dampness, keeping notwithstanding a specific gravity less than that of the air which surrounds it, and by its expansion, presenting the form of a mushroom or the head of a pine with or without the prolongation or appendage towards the base, which appendage, cloudy and opaque, shows a space where the expansion and the cold are at their maximum, and where, consequently, the precipitation of vapor commences almost immediately above the ground or the surface of the sea.

Such are then the principal points which Mr. Espy has obtained from numerous observations. The motion of the air towards the centre of the meteor, the depression of the barometer in the centre, the central ascending current, the formation of cloud at a certain height, and its circular expansion after this cloud has attained a prodigious height, an expansion accompanied with rain and hail, and finally, the motion of the whole meteor, *en masse;* these, I say, are the points which the extensive labors of Mr. Espy, his own observations, and the documents which he has collected, and which he intends publishing immediately in a special work, have placed beyond doubt, and which seem even to have triumphed over every objection, and to have rallied all opinions to his own.

Let us now see the theory upon which he bases his observations, or rather which is based upon these facts well observed, well proven, and always reproduced in nature with similar circumstances.

Mr. Espy thinks that if a very extended stratum of warm and humid air at rest, covers the surface of a region of land or sea, and that by any cause whatever, for example a less local density, an ascending current is formed in this mass of humid air, the ascending force, instead of diminishing in consequence of the elevation of the rising column, will increase with the height of the column, exactly as though a current of hydrogen was rising through the common air, which current would be pushed towards the top of the atmosphere, with a force and velocity in proportion to its height. This column of heated air may also be compared to that in chimneys and stove-pipes, of which the draught is in proportion to the height of the pipe containing the warm air. What then is the cause which renders the warm and humid ascending current, lighter in each of its parts, than the air which is found at the same height with these different portions of the ascending column?

This cause, according to the *sufficiently exact* calculations [*tres suffisament exact*] of Mr. Espy, is the constantly higher temperature which the ascending column retains, and which proceeds from the heat furnished by the partial condensation of the vapor mixed

with the air, making this ascending column a true column of heated air, that is to say, of a lighter gas; for the weight of the water which passes into the liquid state, is far from compensating the excess of levity which proceeds from the more elevated temperature which the air preserves. (This weight only equals one fifth of the diminution of the weight in ordinary circumstances.)

Thus, the higher the column is, the greater is the ascending force, and the rushing in of the surrounding air on all sides will be produced with more energy. To understand this effect better, let us consider a mass of warm and dry air rising in the midst of a colder atmosphere. In proportion as this air rises, it will expand, because of the less pressure which it will experience, and consequently become colder; it will arrive then quickly at an equilibrium both of temperature and pressure with a layer more or less elevated, which it will soon reach, and in which it will remain; but if this only cause of cold, expansion, is overbalanced by a cause of heat, for example the heat furnished by the vapor which is condensing, this air will remain constantly warmer than would have been necessary to attain the same temperature and pressure as the surrounding air. It will then be constantly lighter, and the higher the column, the greater the ascending force.

The calculations of Mr. Espy show, without the slightest doubt, that the column of damp air regaining in temperature, by the condensing of the vapor, a part of the heat lost by expansion; this column always remains warmer than the air which is at the same height with each of its parts. Finally, Mr. Espy furnishes the exact data which are still wanting to science, by the experiments made upon the temperature which the air preserves by the effect of condensation of the vapor in a closed vessel which he calls a "nephelescope," and in which he compares the thermometrical fall produced in the air by a diminution of superincumbent pressure, to what takes place in nature, whether operating on dry, or employing damp, air. Notwithstanding the influence of the sides of the vessel, every time a light cloud is formed in the apparatus, the temperature undergoes a much less reduction than that which takes place when the point of precipitation of vapor has not been attained, or when the experiment is tried on dry air.

The theory of Mr. Espy also accounts very well for the formation of a true cloud analogous to the cumulus with horizontal base, from the moment when the warm and damp air has acquired such an expansion, that the cold produced by it will cause a precipitation of water, and the base of the central cloud of the tornado, if it is horizontal, as is the case in the great meteors of this nature, should be lowered in proportion as the moist air which is carried up is more fully charged with vapor; this base, like that of the cumulus, being of necessity found at the point where the temper-

ature of the ascending current becomes that of the *dew point*, which itself depends evidently upon the degree of dampness of the air. This theory further explains how, in the small tornadoes, whose violence is remarkable, an expansion takes place in the centre of the meteor, at a very small height, sufficient to condense vapor by the cold and consequently to produce this kind of appendage which particularly distinguishes small tornadoes, or common water spouts. Let us add that the calculations of Mr. Espy, upon the density of the warm column, its comparative levity, the ascending force of the current, the central depression which is the consequence of it, the rapidity with which the surrounding air rushes towards the place where the pressure is diminished, finally all the conclusions drawn from the physical data of the phenomena have been proved and ascertained with sufficient exactness to leave no doubt as to this portion of Mr. Espy's theory.

One word remains to be said relative to the progressive movement of the meteor. This movement may depend upon an ordinary wind, which, imparting a common motion to the whole atmosphere, would not disturb the ascension of the column of moist air. But as these phenomena are produced suddenly in the midst of a great calm, Mr. Espy thinks that, in accordance with observed facts, the motion of the meteor should be attributed to the winds, which predominate in the upper part of the atmosphere, and that in modern latitudes, this motion should thus take place towards the east, whilst in the equatorial regions this motion should be directed towards the west, as the current of the trade winds. In a word, the slight surcharge which is owing to the spreading out of the air, around the top of the meteor, accounts for the trifling elevation of the barometer, which the invasion of the tornado, in every place presents, and can even, according to Mr. Espy, serve as a prognostic of it.[1] Another result is, that beyond the limits of the meteor, a feeble wind ought to be observed, as is the case, whose direction is opposite to that of the air which is violently rushing towards the centre of the tornado.

The consequences which Mr. Espy deduces from this theory, are, that in many localities, in Jamaica, for example, the sea breezes cause a motion of the air perfectly analogous to that which constitutes a tornado, and that the results of it are the same, namely, rain and tempest at stated hours, on each day of summer. The same circumstances produce the same effects in other well known localities, volcanic eruptions, great conflagrations of forests, with the favorable circumstances of tranquillity, heat, and moisture, ought also to produce ascending currents and rain. In the midst of all the theoretical deductions of Mr. Espy, it should be remark-

[1] The reader will recollect that in the "Report," *tornado* is used to signify both large and small storms.

ed, that a descending current of air never can communicate cold, for this current would become warm by compression in proportion as it should descend, and the meteorological temperature of many places sheltered from the ascending winds, is considerably augmented by this cause. The tempests of sand in many parts of Africa and Asia, although possessing much less violence, owing to the dryness of the heated air, accord perfectly with the theory of Mr. Espy, both as to quantity and the nature of their effects.

Lastly, let us observe, that if, in tornadoes, the air is absorbed by the lower portion of the column, and not by the higher parts, it is, that the difference between the pressure of the heated column, and that of the surrounding air, is much more marked, as it is considered lower down, in the column of less density and equal elasticity, so that, in the case of an equilibrium, at the lowest point this difference would be precisely the total difference of the whole heated column to the whole column of air of the same height situated around the first. The observations and experiments which have been suggested to Mr. Espy by the study of the phenomena of tornadoes, and the theory he has given of them merit the most serious attention. It is very evident that science would be much benefited by the establishment of a system of simultaneous observations of the barometer, thermometer, hygrometer, and especially of the anemometer, if at least they could be procured capable of giving with sufficient accuracy the intensity of the wind at the same time with its direction and the time of each variation of force. The influence which electricity exerts in this phenomenon, remains yet to be determined. Mr. Espy thinks that artificial causes, for example, great fires kindled in favorable circumstances of heat, of tranquillity, and humidity, can cause an ascending column of much less violence, the useful results of which would be on the one hand rain, and on the other the happy prevention of disastrous storms. It will be necessary to see in Mr. Espy's work itself, the further beneficial results to navigation from the views furnished by his theory.

The different manners in which philosophers, by means of apparatus whose principle of action is the centrifugal force, have imitated water-spouts or small tornadoes, do not appear to us reconcilable with Mr. Espy's theory, which, based upon facts, equally refutes the idea of a whirling motion of the air in the tornado.[1]

[1] Philosophical Magazine, for June, 1841. Sir David Brewster says, "the theory of the rotatory character of storms was first suggested by Col. Capper, but we must claim for Mr. Redfield the greater honor of having fully investigated the subject, and apparently established the theory upon an impregnable basis."

Here we should compare the theory of Mr. Espy with other theories, anterior or contemporaneous. The labors of Franklin, and of Messrs. Redfield, Reid, and Peltier would furnish as many excellent observations and parts, or the whole of the phenomena, very well studied. But the extensive discussion which we should have to establish before deciding in favor of Mr. Espy, would lead us too far. Mr. Espy himself, as to the electrical part of the phenomenon, which, however, he regards as only accessory and secondary, acknowledges that his theory is less advanced and less complete than it is with regard to the phenomena of the motion and precipitation of the water, which are, according to him, the base of the production of the meteor.

Finally, it is proved by the investigations of Mr. Espy, that it will be impossible hereafter to adduce in the mean [normale] state of the atmosphere, a descending current of air as a cause of cold, or an ascending current of dry air, a cause of heat. The applications of this theory present themselves in "climatology," but this principle especially discards the idea of explanation of the tornado by the centrifugal force, which would then cause the upper air to descend in the centre of the tornado, which air becoming heated by the augmented pressure, could not allow its own vapor to be precipitated nor precipitate that of the air with which it came in contact.

CONCLUSION.

In conclusion, Mr. Espy's communication contains a great number of well-observed and well-described facts. His theory, in the present state of science, alone accounts for the phenomena, and, when completed, as Mr. Espy intends, by the study of the action of electricity when it intervenes, will leave nothing to be desired. In a word, for physical geography, agriculture, navigation, and meteorology, it gives us new explanations, indications useful for ulterior researches, and redresses many accredited errors.

The committee expresses then, the wish that Mr. Espy should be placed by the government of the United States in a position to continue his important investigations, and to complete his theory, already so remarkable, by means of all the observations and all experiments which the deductions even of his theory may suggest to him, in a vast country, where enlightened men are not wanting to science, and which is besides, as it were, the home of these fearful meteors.

The work of Mr. Espy causes us to feel the necessity of undertaking a retrospective examination of the numerous documents already collected in Europe, to arrange them and draw from them deductions which they can furnish, and more especially at the present period, when the diluvial rains, which have ravaged the south east of France, have directed attention to all the possible

causes of similar phenomena. Consequently, the committee proposes to the Academy to give its approbation to the labors of Mr. Espy, and to solicit him to continue his researches, and especially to try to ascertain the influence which electricity exerts in these great phenomena, of which a complete theory will be one of the most precious acquisitions of modern science.

The conclusions of this report are adopted.

NOTE.

I have stated in the Synopsis, that islands, with high mountains in them, are more likely to have rains from sea breezes, than those without mountains. The following facts go to confirm that position, and they will be easily understood from the theory, without further explanation. Certainly they are not to be explained by any supposed attraction of mountains for clouds, as is asserted by the author of the American Almanack, and by many higher authorities. The facts, indeed, which Mr. Borden gives, prove that the cloud is not attracted to the mountain, but formed there.

Dr. Campbell, of Lancaster, England, observes, "that the influence of hills, in attracting clouds, is nowhere more conspicuous than at Kendall ; that one third more rain falls at Kendall than at Lancaster, a distance of only twenty miles, and that it is by no means unusual to see from the church yard at Lancaster, the hills about Kendall enveloped in thick clouds, while the sky at the Lancaster side of Farlton Knott appears perfectly clear. And Dr. Garnett says, the summer of 1792 was remarkably dry in Yorkshire, and all the eastern side of the English Appennine was burnt up for want of rain ; while, on the western, they had plenty of rain and abundant grass." [Transac. of Royal Irish Acad., vol. xvii. p. 224.

"That the mist should remain so nearly stationary on the top of Table Hill, while the south east wind continues, is not surprising, considering the height of the hill, 3582 feet above the level of the sea, its precipitous sides, and the extensive surface of its top ; nor is it strange that it should rarely descend, except when the wind blows hard, taking into account the situation of the ground beneath, sheltered and warm, and the site of a large town, from which a current of hot air must constantly be rising." [Mr. John Davy. Tilloch's Magazine, vol. li. p. 35.

"The air on the summit, which rises to the height of 3582 feet above the level of Table Bay, in the clear weather of winter, and in the shade, is generally about fifteen degrees of Fahrenheit's scale lower than in Cape Town. In the summer season the difference is much greater, when that well known appearance of the fleecy cloud, not inaptly called the table cloth, envelopes the summit of the mountain. In the heat of the summer season, when the south east monsoon blows strong at sea, the water taken up by evaporation is borne in the air to the continental mountains, where, being condensed, it rests on their summits in the form of a thick cloud. This cloud, and a low dense bank of fog on the sea, are the precursors of a similar but lighter fleece on the Table Mountain, and of a strong gale of wind in Cape Town from the south east. These effects may be thus accounted for: The condensed air on the summit of the mountains of the continent, rushes, by its superior gravity, towards the more rarefied atmosphere over the isthmus, and the vapor it contains is there taken up and held invisible, or in transparent solution. From hence it is carried by the south east winds towards the Table and its neighboring mountains, where, by condensation from decreased temperature and concussion, the air is no longer capable of holding the vapor with which it was loaded, but is obliged to let it go. The atmosphere

on the summit of the mountain becomes turbid, the cloud is shortly formed, and, hurried by the wind over the verge of the precipice in large fleecy volumes, rolls down the steep sides towards the plain, threatening momentarily to deluge the town. No sooner, however, does it arrive in its descent at the point of temperature equal to that of the atmosphere in which it has floated over the isthmus, than it is once more taken up, and 'vanishes into air — to thin air.' " [John Barton. Tilloch, vol. x. p. 225.

The doctrine of concussion producing condensation of aqueous vapor, has no foundation in nature. It is surprising to me, that Mr. Barton should not have known the principle, that cold, by the expansion of the air as it ascends the sides of mountains, is sufficient to produce condensation. It is a principle long familiar to the scientific world, and it is one which I used in my early writings, as belonging to the great storehouse of science, as common property, without even inquiring who was the original discoverer, or who first saw a cloud form in the receiver of an air pump on extracting the air. Mr. H. Meikle claims this discovery as original. So far as I am concerned, he shall never be deprived of that honor; I lay no claim to it. (See Appendix, page 547.)

Facts communicated by Simeon Borden, Esq., of Boston. "In the western part of the state of Massachusetts, there are many mountains of considerable elevation. Amongst them I have spent much time in the course of three or four years just past. The following phenomena are of almost every day occurrence:

"One day, as I was standing near the base of the Watatick mountain, (a mountain about two thousand feet in height,) looking at the clouds, which were apparently resting upon its top at that time, — the wind was blowing briskly from some southerly point; the day was remarkably pleasant, the sun shone brilliantly, and the cloud which capt the mountain was not large, — I observed frequently, upon the windward side of the mountain's top, that many square yards of transparent atmosphere would occasionally become suddenly transformed into a dense fog or cloud, which would then pass with the current of the atmosphere across the top of the mountain, and would then as suddenly vanish into transparent atmosphere again, resembling in its transformation, very much in form or shape, that of *a vanishing flame of fire.* I noticed at other times, that although the wind would frequently be blowing briskly, still the cloud would apparently remain stationary upon the mountain top; sometimes it would however appear to enlarge, and then again would diminish, and pretty uniformly in fair weather would rise from and leave the mountain top entirely near midday."